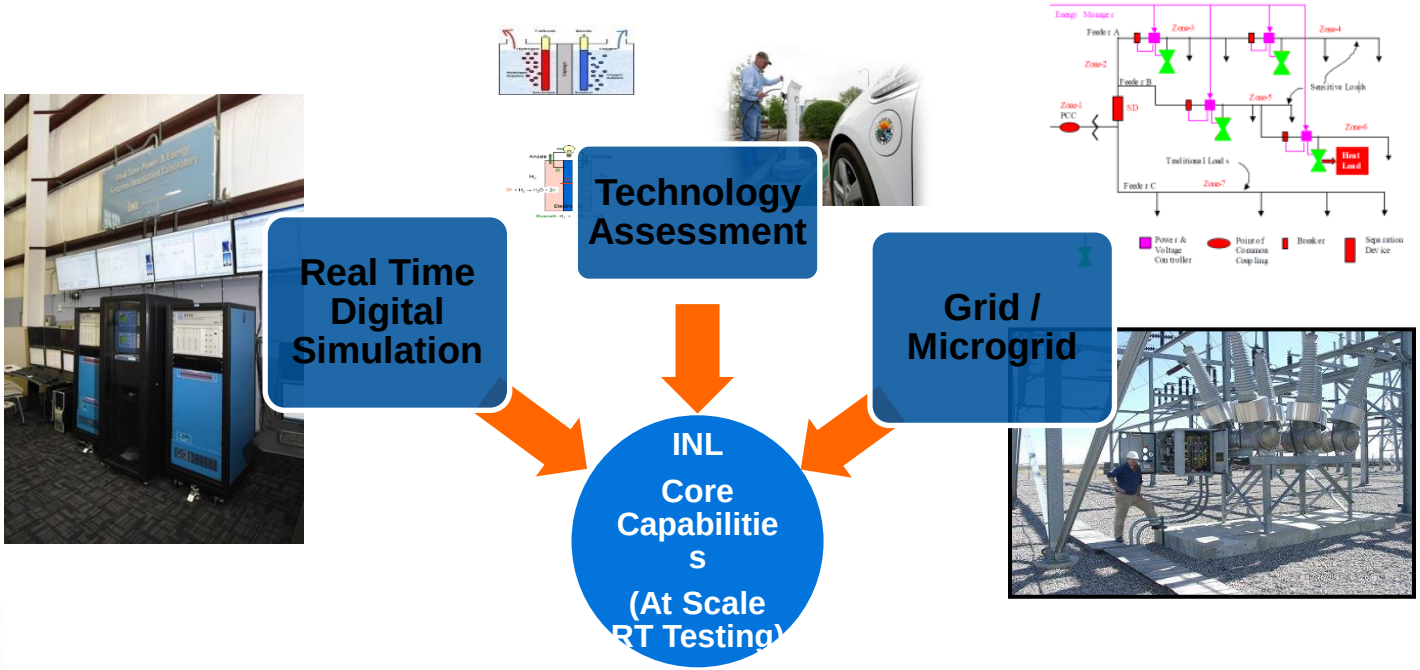
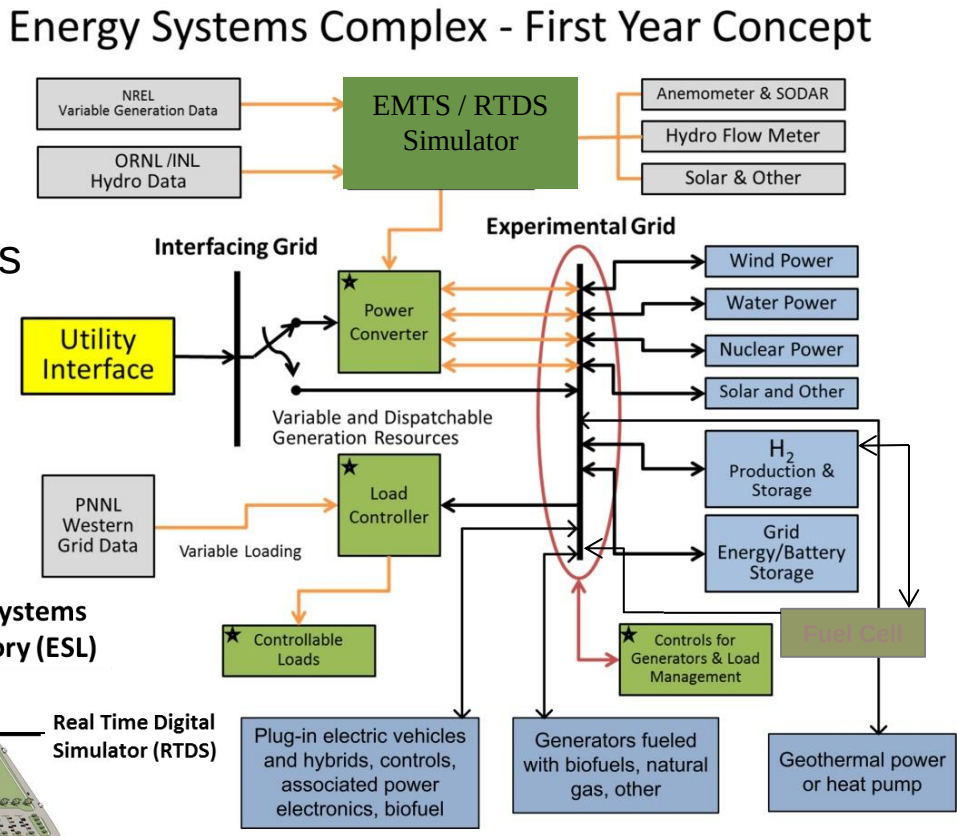
Real Time Power & Energy Laboratory

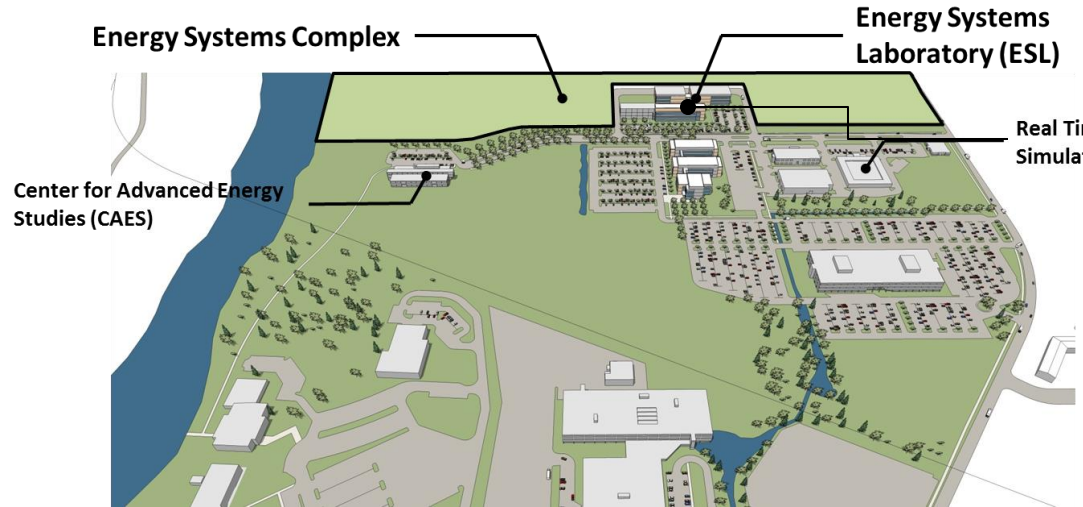


Rob Hovsapian, PhD

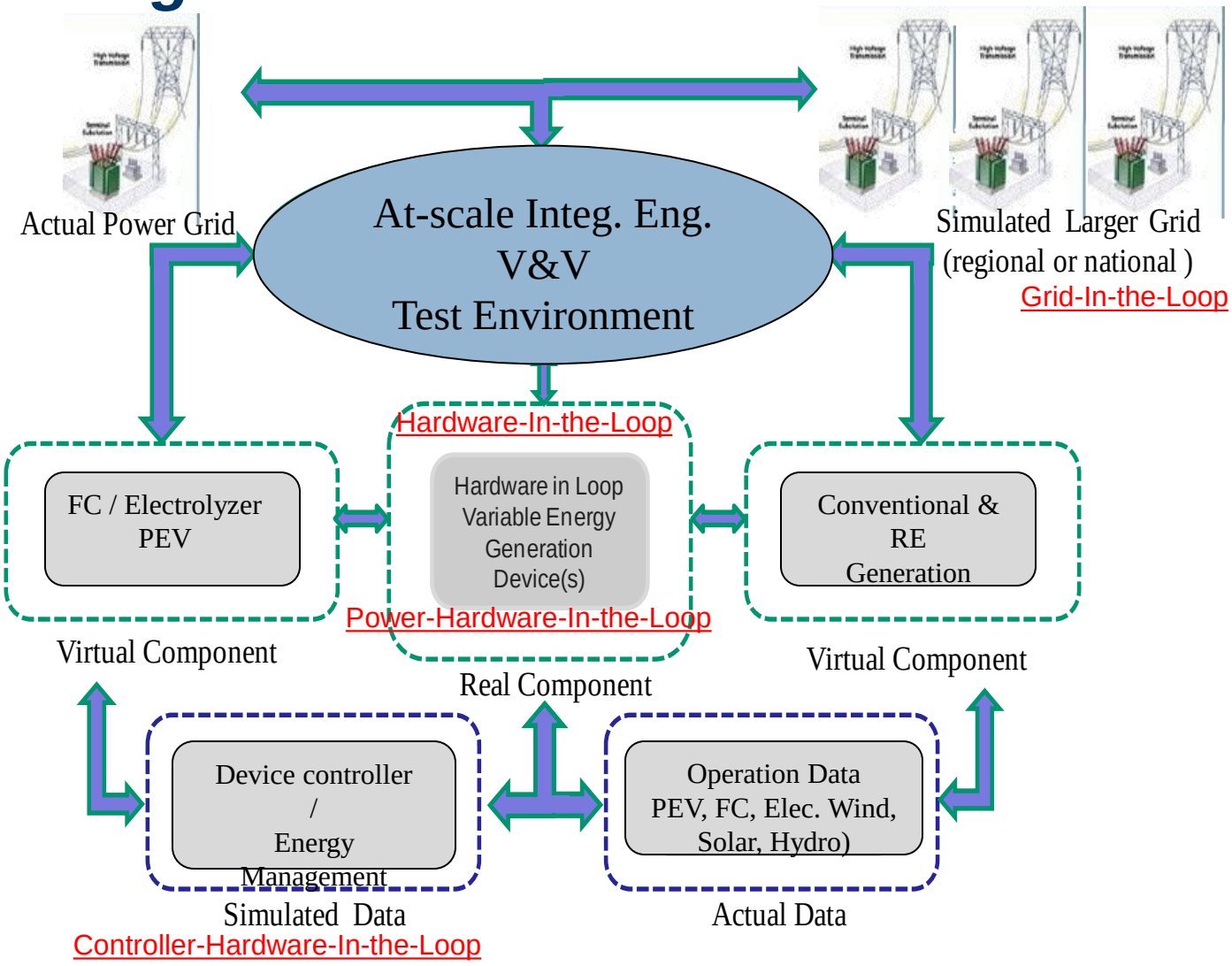
INL Energy Systems Laboratory's Demonstration Complex and Test Bed

- For the renewable technologies
  - Modeling, simulation, and hardware-in-the-loop capabilities for demonstrations and dynamic analysis
    - Energy farms
    - Integration with HES
    - Control and integration strategies
    - Coupling with energy storage





Real-Time Hardware-In-the-Loop Modeling and Testing Environment

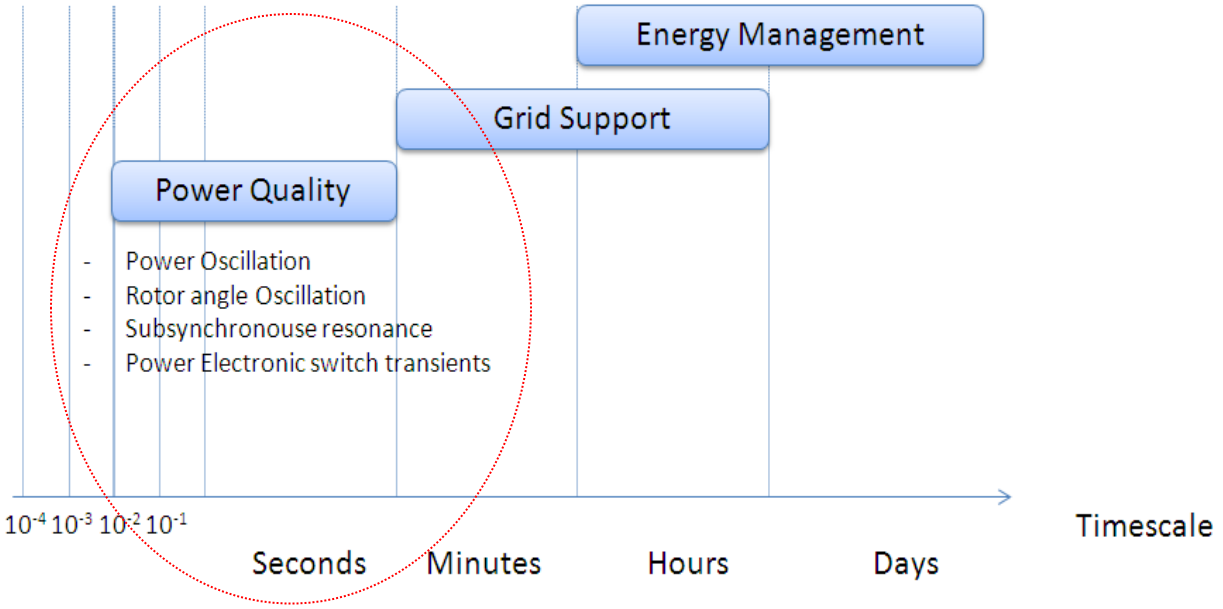


INL Energy Systems Integration Group Differentiating Competence

Dynamic and transient behavior of energy systems interaction under various transient phenomena

From Grid Tech Planning Meeting:
Problem - Insufficient capabilities to **Predict transients (microseconds – seconds)**

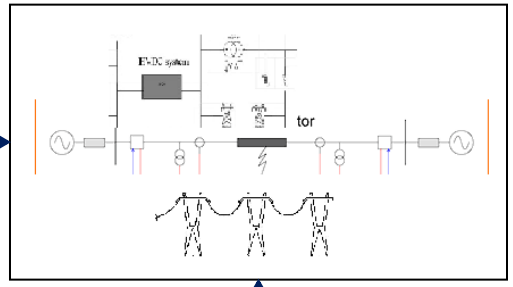
- High-fidelity power and Energy system interaction
- Understand and predict the transient behavior of energy systems at 50 μs (2 μs non real time) time steps
- Establish Hardware-In-the-Loop (HIL), Controller-In-the-Loop and Grid-In-the-Loop testing environments with real world field measurements.



Integrated Grid Environment - Electrical / Mechanical / Thermal Co-Simulation

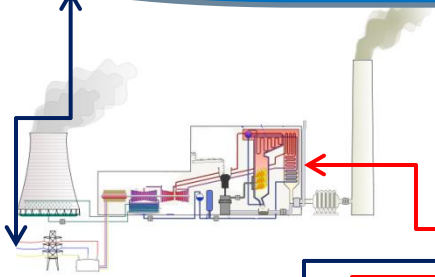
RTDS/ (Other Sites)

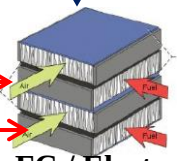
RTDS/INL



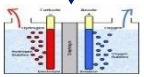
Power System Models

finite state machine

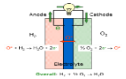




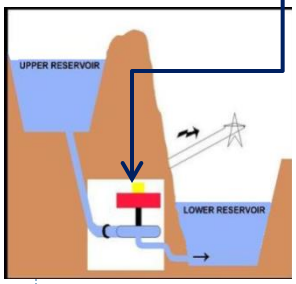
HT – FC / Electrolyzer

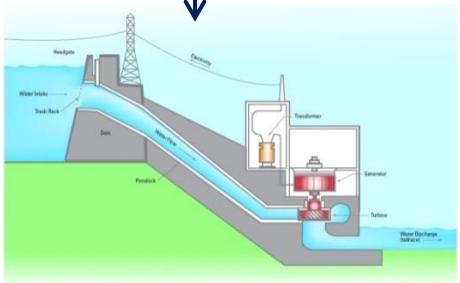


Electrolyzer

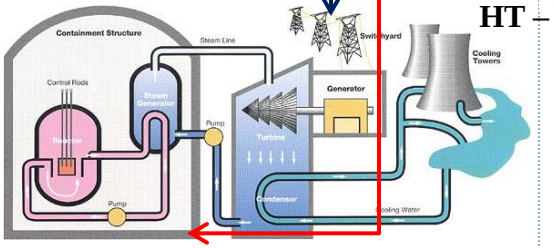


Fuel Cell





Hydropower Plant Models



Thermal Power Plant Models

Energy Storage Models

V2G

Leveraging Other National Labs and Academic Institutes Via Strategic Partnerships

Idaho National Laboratory

INL
- Power System Grid Test Bed
- Wireless Test Bed
- SCADA / Cyber Security Test Bed
- Energy Systems Laboratory

NREL
- Energy Systems Integration Facility
- National Wind Technology Center

ANL
- Pump Hydro Energy Storage Systems

SNL
- Energy Storage Test Program
- SCADA Test Bed

PNNL
- NorthWest GridWise Testbed
- Grid Monitoring of the WECC

Washington State Univ.
- Real time modeling

LBL
- Microgrid Test Bed
- Integration

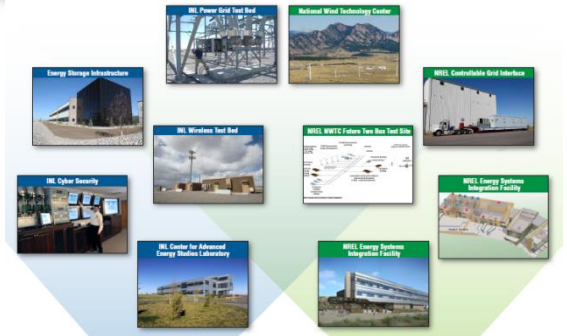
CAES –
UI, ISU, BSU

Florida State Univ.
- 5 MW Grid simulator

Univ. of Texas at Austin.
- Physics Based Modeling

Colorado State Univ.
- Power System Dynamic Modeling

Univ. of New Mexico
- Wind Dynamic Modeling



RTDS Link

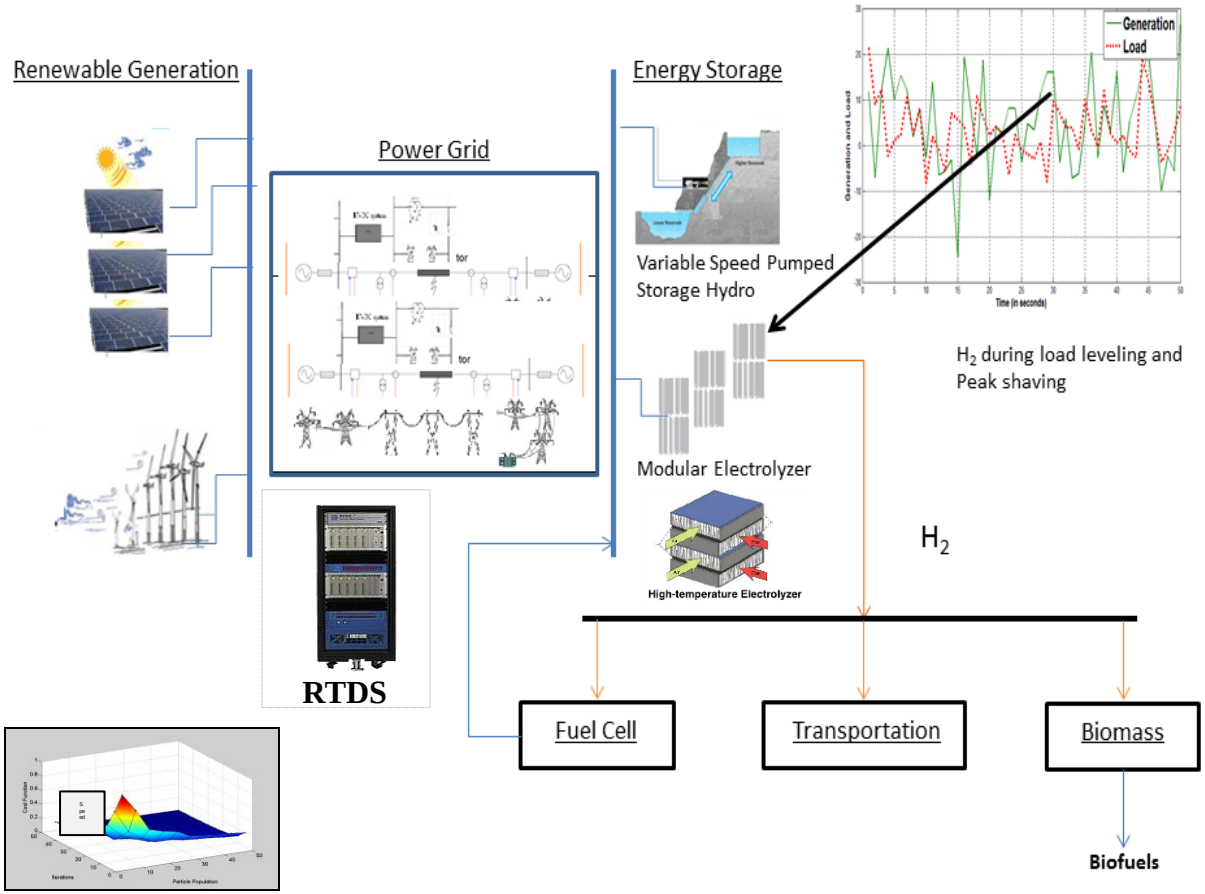
INL NREL

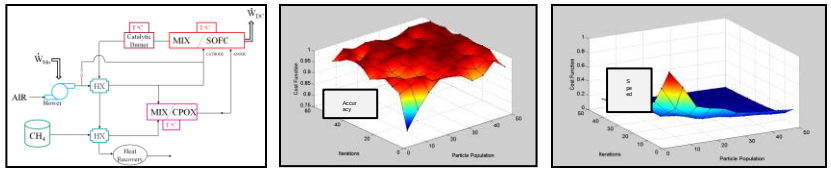
SIEMENS TESLA SDGE A Sempra Energy utility PG&E California ISO Shaping a Renewed Future

Projects

Dynamic Modeling and Validation of Fuel Cell/ Electrolyzers in a Real Time Environment

- Holistic system perspective
- Real time characterized and validated models
- Technical performance and value proposition for grid-scale deployment
  - Microgrid (CERTS/NREL/INL)
  - Distribution & Transmission



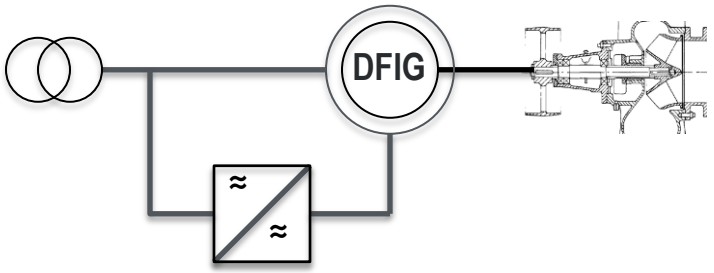


Objective: Leveraging DoE Lab assets located across wide geographical distances to study the impact of fuel cell / electrolyzers on grid distribution systems

Pumped Storage Hydropower (PSH) Transient Simulation Modeling

Idaho National Laboratory

- Develop transient PSCAD models in small time steps (5 -50 μs) to better understand the dynamic interactions between electromagnetics and hydrodynamics.
- Study the hydrodynamic behaviors such as water hammering and flywheel effects due to sudden load and fault conditions.
- Conduct System level testing and analysis on the Real Time Digital Simulator
- Provide a greater understanding of variable renewable interactions and the value of energy storage.



Co-simulation of the Electromagnetic & hydrodynamic Transients

Argonne NATIONAL LABORATORY
NREL NATIONAL RENEWABLE ENERGY LABORATORY
THE UNIVERSITY OF TEXAS AT AUSTIN

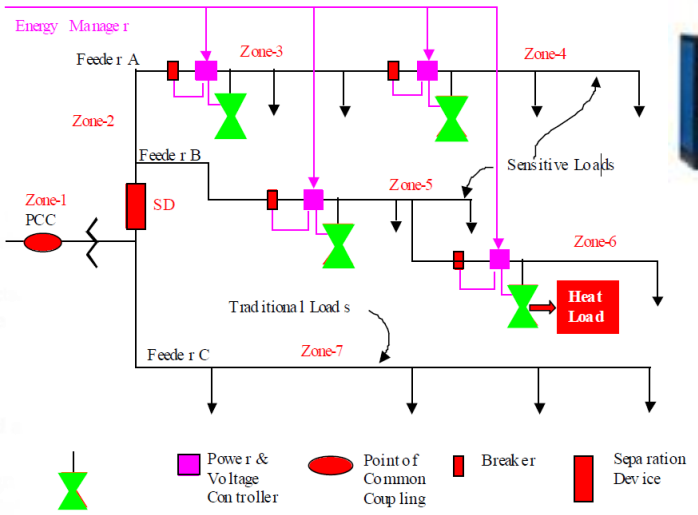
Dynamic CERTS Microgrid Test-Bed on RTDS

The U.S. Department of Energy's Microgrid Initiative

The DOE Smart Grid R&D Program considers microgrids as a key building block for a Smart Grid and has established microgrid R&D as a key focus area. A significant number of R&D needs and challenges have been identified for microgrids during two workshops, with input from more than 170 experts and practitioners representing a broad group of stakeholders.

Dan T. Ton and Merrill A. Smith

(LBNL) is teaming with American Electric Power (AEP), the University of Wisconsin, and Sandia National Laboratories (SNL) to apply Consortium for Electric Reliability Technology Solutions (CERTS) microgrid concepts in AEP's Dolan Technology Center-Walnut Station Test Facility in Groveport, Ohio. CERTS microgrid concepts are also being applied in field demonstrations by the Sacramento Municipal Utility



- Loads & Distribution System data for CERTS Microgrid is not available

Key Points

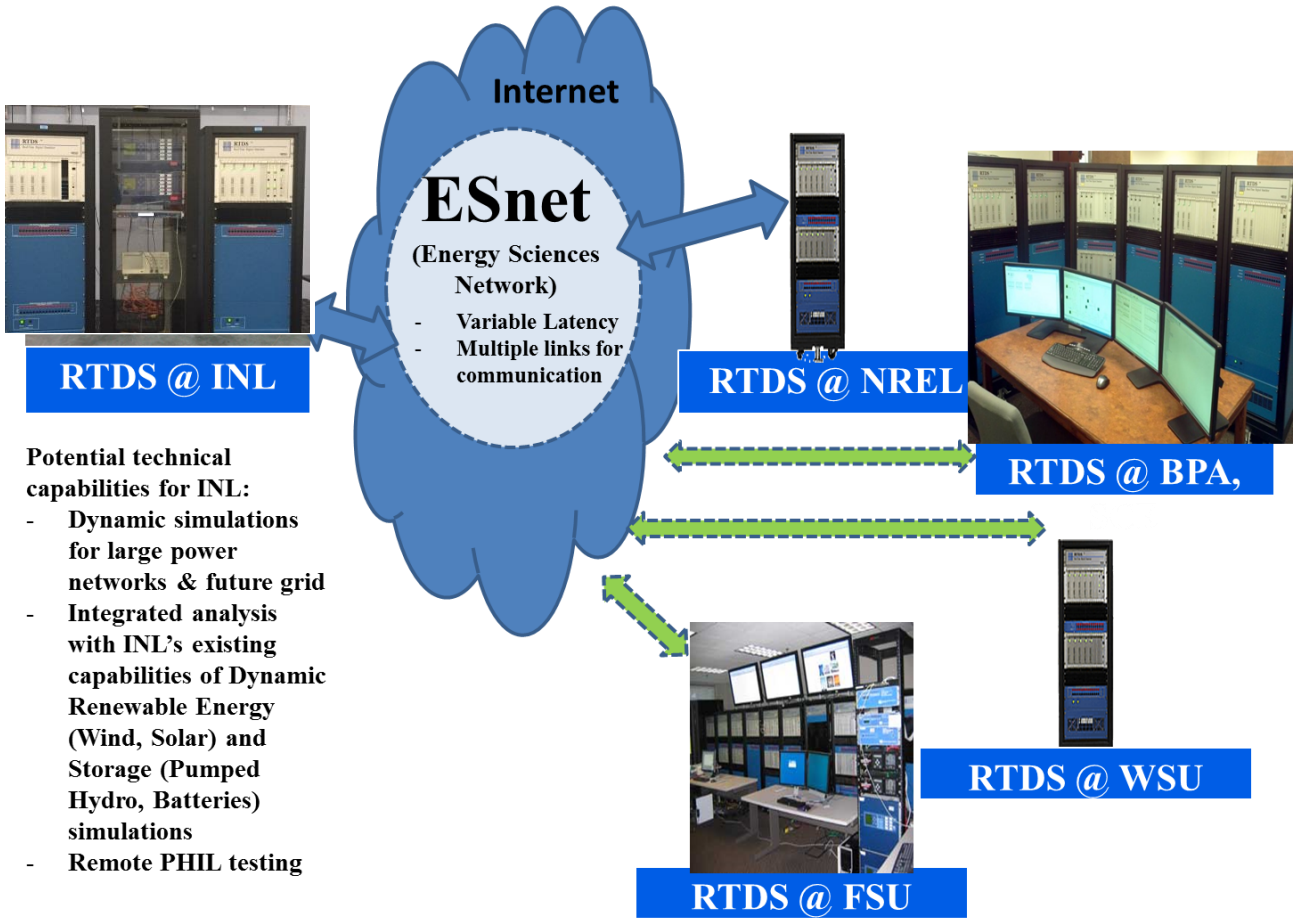
- Point of Common Coupling (PCC) - Transition from Grid-Connected to Islanded Mode & vice-versa
- Higher reliability for Critical/Sensitive Loads
- Distributed Renewable Generation
- IEEE Interconnection, Power Quality & IEC Communication standards

Washington State University Colorado State University

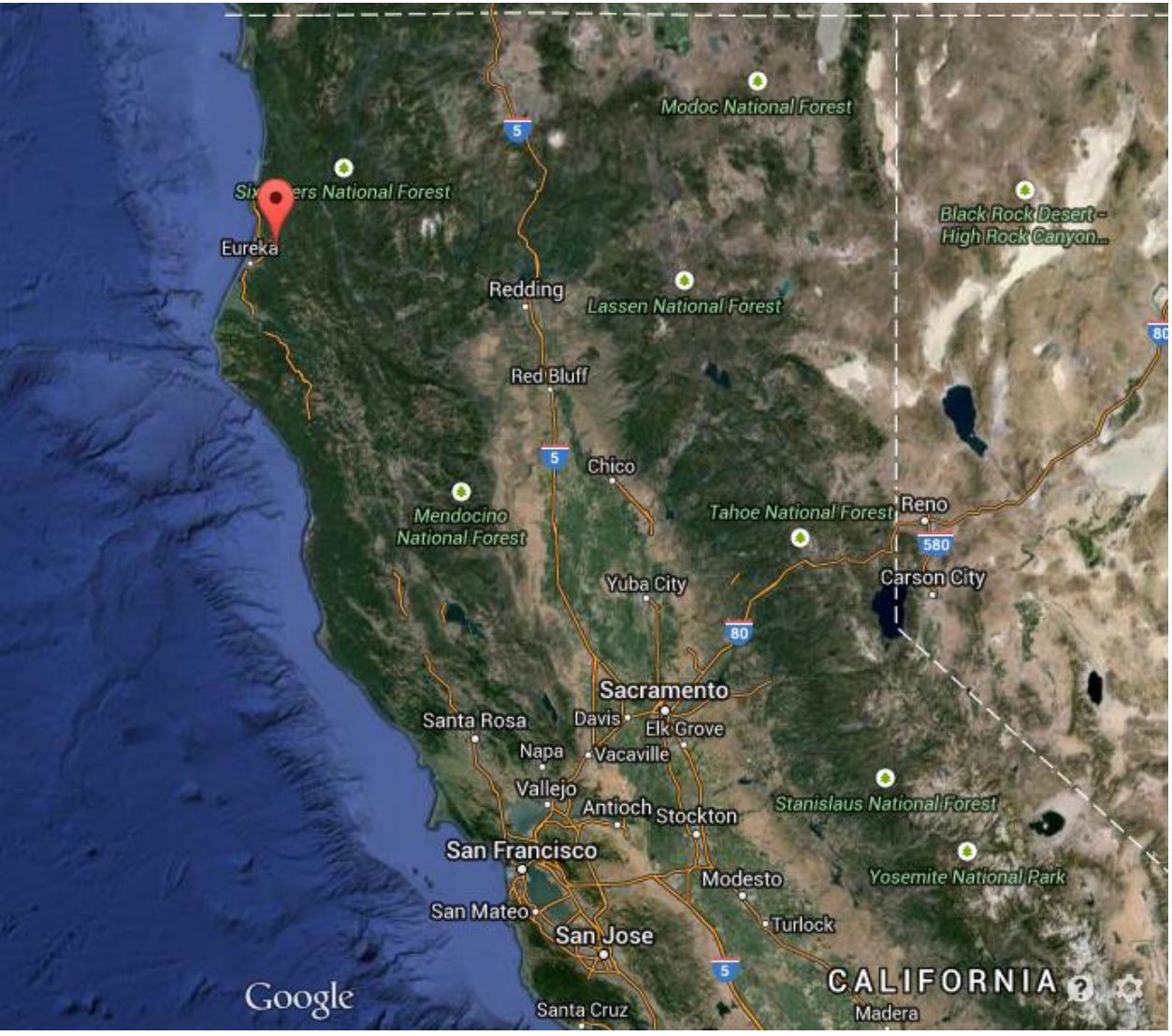
Dynamic Simulations for Large Scale Electric Power Networks in Real Time Environment using Multiple Real Time Digital Simulators

With broad array of stakeholders, **academic** institutions, **utility** companies, and National Labs

- To develop simulation methods and demonstrate capabilities of large scale dynamic simulations using multiple geographically distributed real time digital simulators
- Ability to analyze events such as voltage collapse and power swings for large networks that can lead to a blackout



INL Current Utility Storage Projects



- Funded by California Energy Commission's Electric Program Investment Charge
- PON-14-301
- **Program Goal:** Demonstration of Low Carbon-Based Microgrids for Critical Facilities
- Partners – INL, Siemens, Tesla (Utility scale Storage) Humboldt University, PG&E

California Energy Commissioner – Project
Future & Existing Energy Infrastructure

North

Solar Array
kW (future)

(Future/New) Grid Battery Storage
and microgrid control room

175kW Renewable Energy (biomass to fuel cell) Distributed Generation Power System (in operation 3/15); 10 days' islanded operation (via biomass fuel storage)

1MW Generator
Diesel powered; 3,000 gallon tank; 50 gallons per hour consumption rate = ~120 hours of islanded operation, depending upon energy use.

Blue Lake Hotel - 2,000A / 480V / 3 phase service; powers hotel + renewable energy system. 102 hotel rooms for shelter in place

Blue Lake Casino – 2,000A / 480V / 3 phase service; powers casino and sapphire palace + receives energy from renewable energy system. 44,000 square feet; 3 restaurants; 4 sets of restrooms

UPS - 2 Liebert (150 kVa and 50 kVa) and 1 MGC (36 kVa) battery banks; 15 minutes of islanded operation (slot machines servers, e-lighting)

CEC- Project Future & Existing Energy Infrastructure

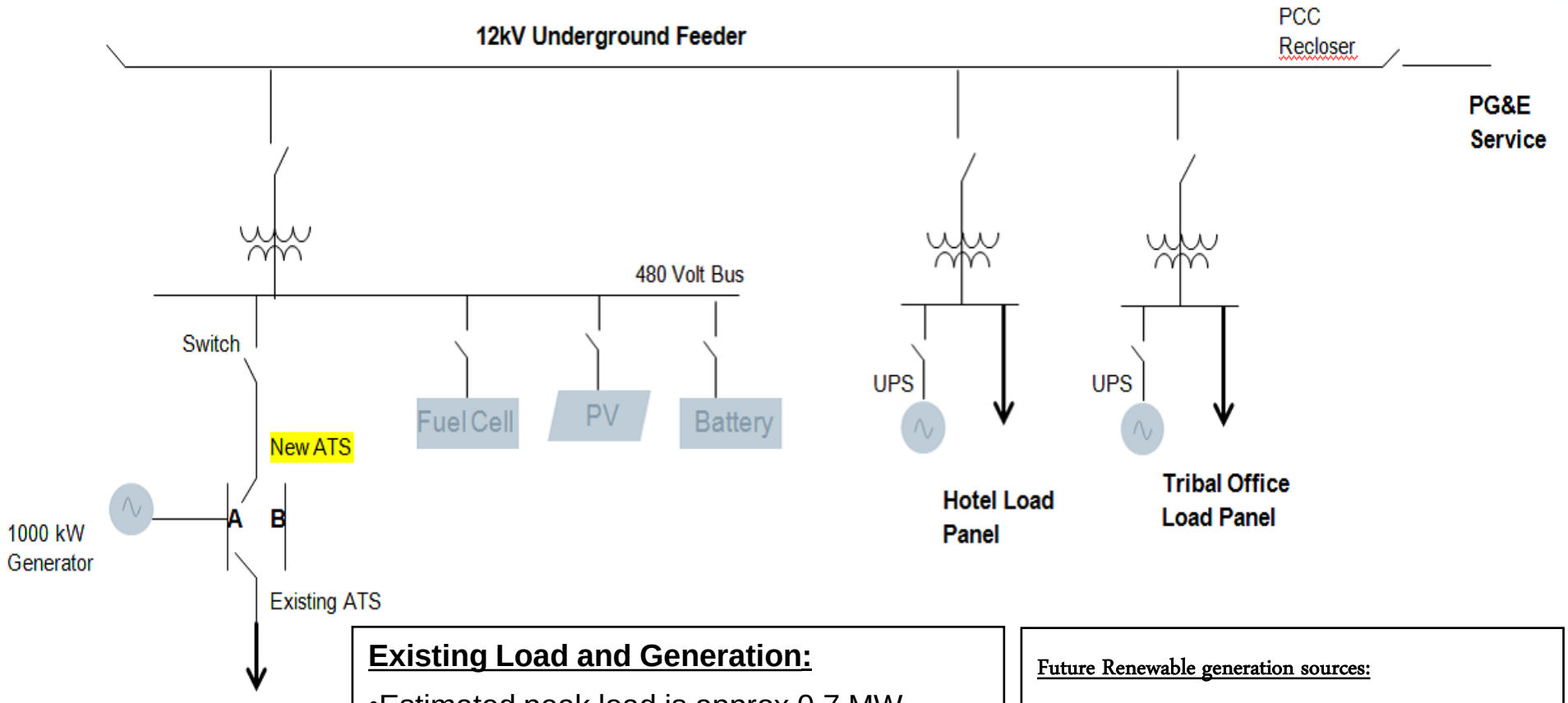
UPS - 2 Liebert (150 kVa and 50 kVa) and 1 MGC (36 kVa) battery banks; 15 minutes of islanded operation (slot machines servers, e-lighting)

Sapphire Palace – receives energy from casino service. 800-person capacity; 1 set of restrooms; available shelter in place and/or medical facility.

Tribal Office – Separate meter. Kitchen facilities, 1 set of restrooms (septic system)

80kW Generator for Tribal Office; ~24 hours of islanded operation

One-Line Diagram of 12kV Line Joining Service Transformers at the Casino, Hotel and Admin Office Bldg



Existing Load and Generation:

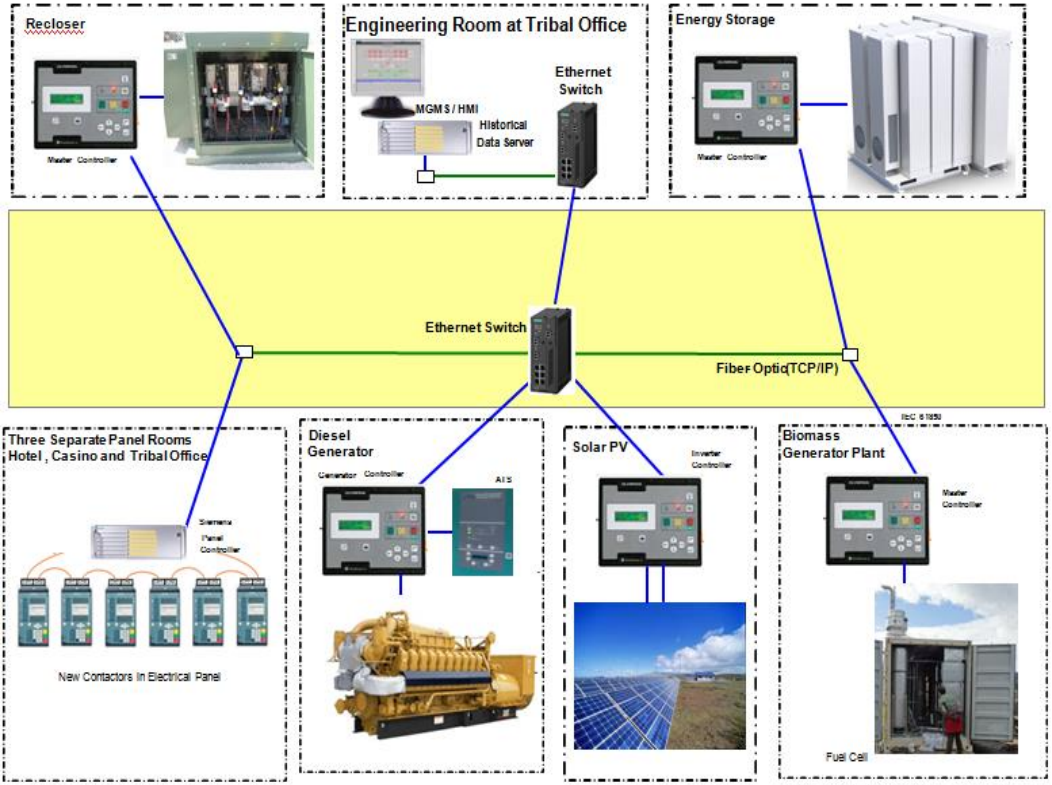
- Estimated peak load is approx 0.7 MW
- Estimated average load is approx 0.5 MW
- Diesel generator for base generation 1 MW
- Fuel cell + biomass 0.175MW

Future Renewable generation sources:

- Solar PV Plant 0.25 MW
- Battery 0.2 MW

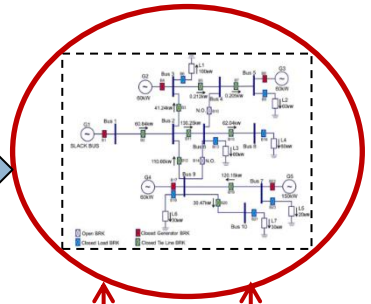
CEC- Project Architecture

Blue Lake Rancheria



Blue Lake Rancheria , CA

PG&E Power System Network

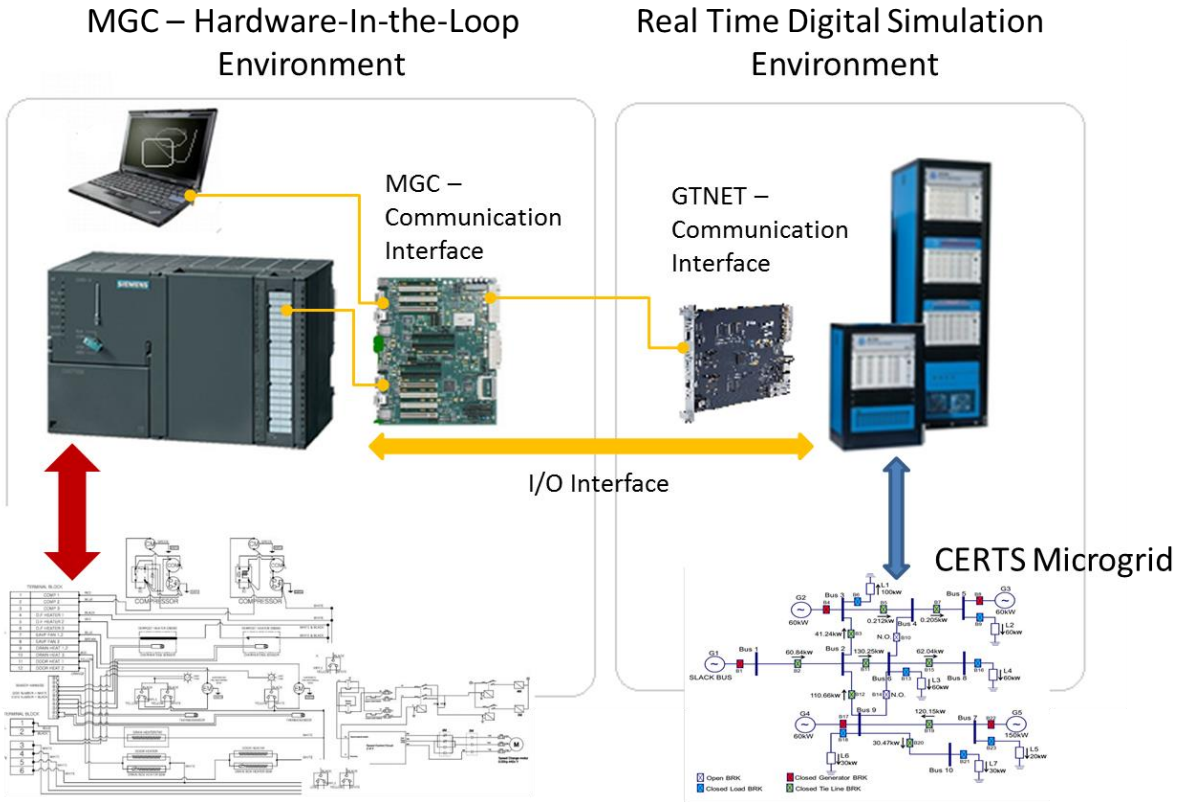


INL

Microgrid Modes of Operation:

1. Grid connected
2. Black start transition
3. Off-grid operation
4. Resynchronization to PG&E network

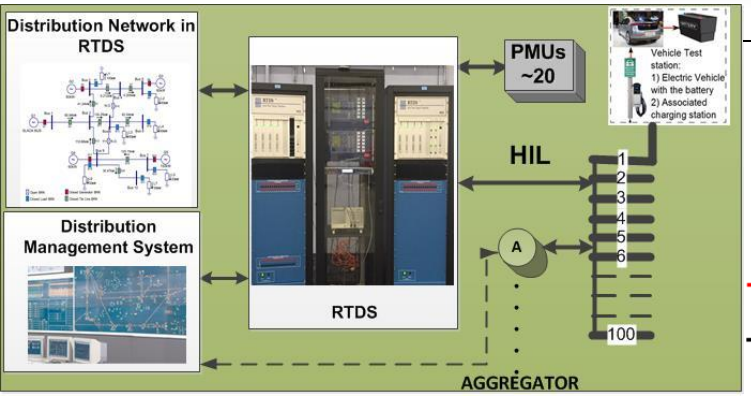
Rapid Development of Controller-Hardware-In-the-Loop Research, Development



SIEMENS

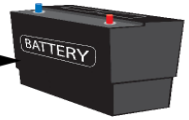
Washington State University

At Scale Battery and Vehicle Charging station and Grid Integration with the Real Time digital Testing



Power Signal

Data Signal



Vehicle Test station:
1) Electric Vehicle with the battery
2) Associated charging station

House Supply

Power Converter

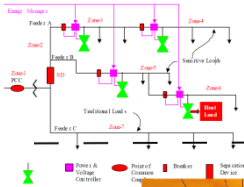
220V/480V, variable current

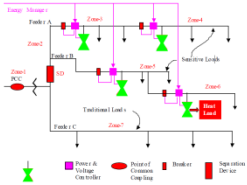
Power Amplifier

House Supply

(To emulate grid dynamics)

Analog signal: 5-10 V,10mA





Analog signal: 5-10 V,10mA

House Supply

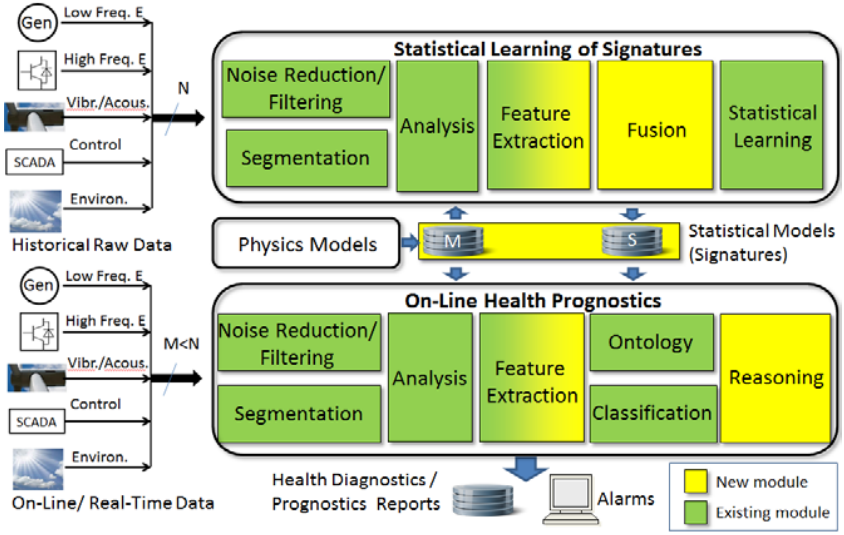
Grid Model (V2G)

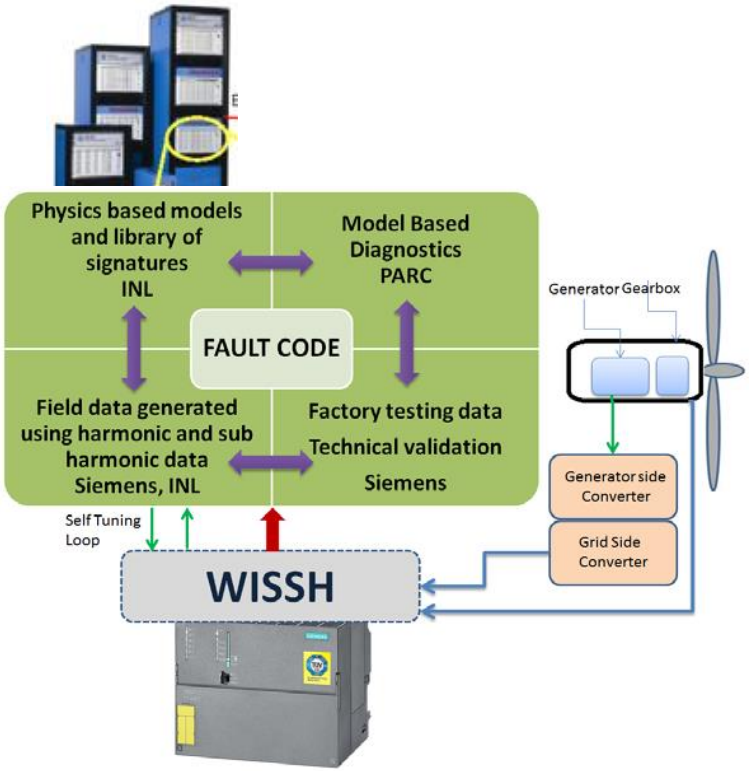
Grid Model G2V

Real Time Digital Simulator (RTDS) and its graphical interface RSCAD

ESL RTDS LAB

Diagnosis and Prognostics Framework by Real-Time Fusion of Electrical, thermal and Mechanical Signals





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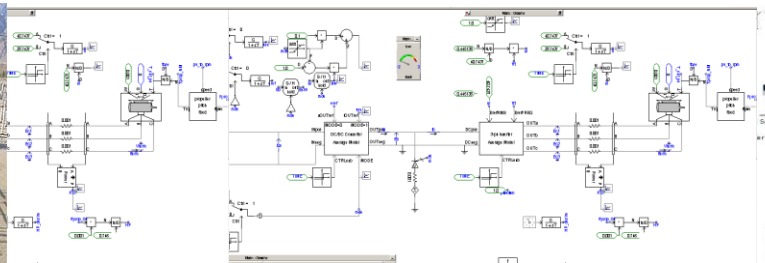
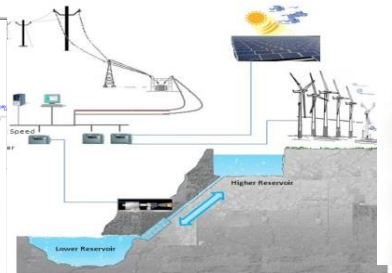
Key Research Questions

- How are ancillary service provided by variable generation
  - How can they contribute into grid reliability improvement and cost of energy reduction
- How smart grid technologies can be implemented and expanded in “Large Grid” applications
- How much renewable penetration can be supported by the existing infrastructure. Prediction of Electric Vehicle Penetration
  - What future upgrades and expansions are needed
- What modifications and improvements to grid regulations are needed to accommodate more EV and renewables
- What testing along with changes, modifications, and improvements are needed for various standards of inverter based generation to meet grid interconnection requirements
- Due to fossil fuel plants reductions causing rotational and thermal inertia loses, what value will Hybrid Storage could contribute to the power quality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